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UNITED STATES BANKRUPTCY COURT
SOUTHERN DISTRICT OF NEW YORK

In re:	)	Chapter 11
	)	
FRONTIER COMMUNICATIONS CORPORATION *et al.*,	)	Case No. 20-22476 (RDD)
	)	Judge Robert D. Drain
Reorganized Debtors.	)	(Jointly Administered)

<u>REORGANIZED DEBTORS' TECHNOLOGY TUTORIAL</u>

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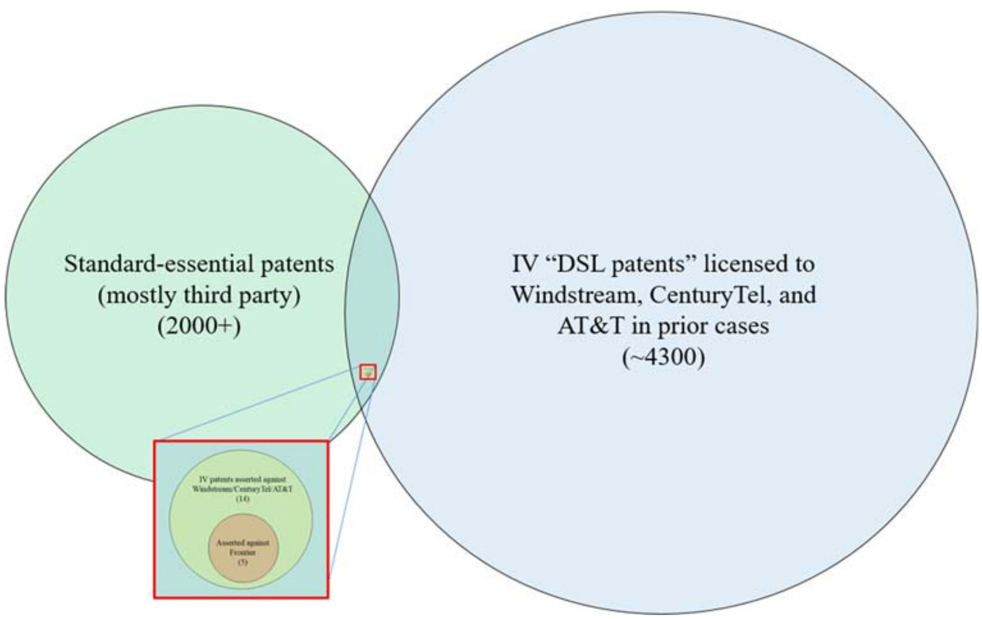
Pursuant to the Court's Scheduling Order (Dkt. 2037), the Reorganized Debtors ("Frontier") respectfully submit the following technology tutorial in advance of the upcoming evidentiary hearing.

I. **INTRODUCTION**

The technology at issue in this dispute concerns tiny features of digital subscriber line ("DSL") data communications protocols. DSL is an older, slower technology (nearly obsolete today), the full scope of which was developed over 25+ years by hundreds of engineers working in tandem and contributing thousands of incremental/accretive details, advances, and features. Some of the features of DSL are patented, some are not; some are formally baked into a DSL "standard" issued by the international governing body (the "ITU-T"), some are not. Critically, the allegedly-patented features asserted here by plaintiff Intellectual Ventures II LLC ("IV") are a small sliver of both (i) the universe of patents allegedly practiced by anyone employing the industry standards, and (ii) the 4300 or so DSL patents that licensed in the prior cases that IV deems "comparable" to this case. Figure 1 illustrates the context:



This tutorial, in short, is a close look at a microscopic portion of the overall DSL picture.

This context matters. As will be explained in Frontier's pre-hearing brief, it is blackletter law that the value of a patent must be assessed on its own technical merits, independent of its adoption into a standard. The fact that a patent may be "standard essential" simply makes it easier (but is not dispositive) for a patent holder to prove infringement. The standard does not itself confer value. Small ideas thus do not become large or valuable by being incorporated into a standard that contains thousands of other features and patents, as here.[1]

II. FUNDAMENTALS OF DSL

A. Physical Architecture and the Basic Model

1. *Digital subscriber line* (DSL) is a general term referring to the transmission and reception of digital data (bits) over twisted-pair lines (subscriber lines) that were originally installed to support conventional (analog) telephone service.

2. DSL is a digital overlay on "top" of conventional voice-band communications. That is, twisted-pair copper wires simultaneously carry both the conventional low-frequency voice signals and the overlaid high-frequency data signals.

3. DSL is implemented – physically – by means of a modem and filter on each end of the "local loop" line, the last mile or so of twisted pair copper wire that connects the

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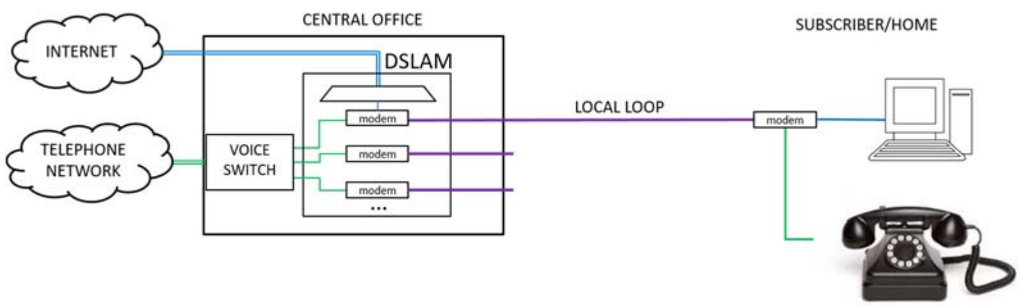
[1] *See, e.g.*, *In re Innovatio IP Ventures, LLC Pat. Litig.*, No. 11 C 9308, 2013 WL 5593609, at *3 (N.D. Ill. Oct. 3, 2013) ("Although the standard-setting process has many potential benefits for consumers, there are dangers. After a standard is established, for example, every manufacturer of compliant products must use the technology stated in the standard. . . . This requirement allows the [patent owner] to charge inflated prices that reflect not only the intrinsic value of its technology, but also the inflated value attributable to its technology's designation as the industry standard. . . [T]his phenomenon [is] often called 'patent hold-up'") (internal citation omitted). The danger is particularly pronounced where the patent owner is neither an inventor nor an operating company but a "patent assertion entity" like IV.

subscriber (*e.g.* home) to the service provider (*e.g.* telephone company central office ("CO")).[2] As shown in figure below, a DSL modem sits at the customer premises. On the other end of the line, a separate DSL modem sits within the DSL Access Multiplexer (DSLAM) located at the telephone company's CO. *See* Fig. 2:



4. At either end of the local loop, the process is similar: data is modulated and placed onto one or more carrier frequencies (described below) via a modem, sent up or down the line, and then taken "off" the line via a modem at the other end. The voice signals and data signals are separated using filters. *Downstream* is defined in DSL as the direction from the service provider to the subscriber; *upstream* is the direction from the subscriber toward the service provider.

B. <u>Signal Modulation</u>

5. To transmit digital information over legacy voice lines, digital 1's and 0's are typically sent by way of one or more modulated "carrier" signals, *i.e.* a semi-fixed analog frequency signal that is altered by the transmitter in a way that the receiver can interpret as 1's and 0's. The carrier signal is modulated (*e.g.* frequency-shifted up or down, phase-shifted,

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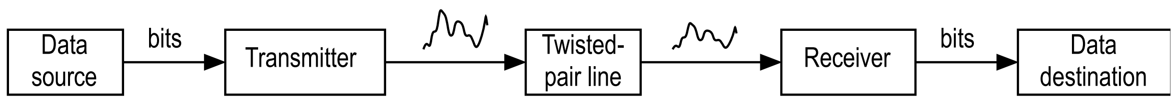
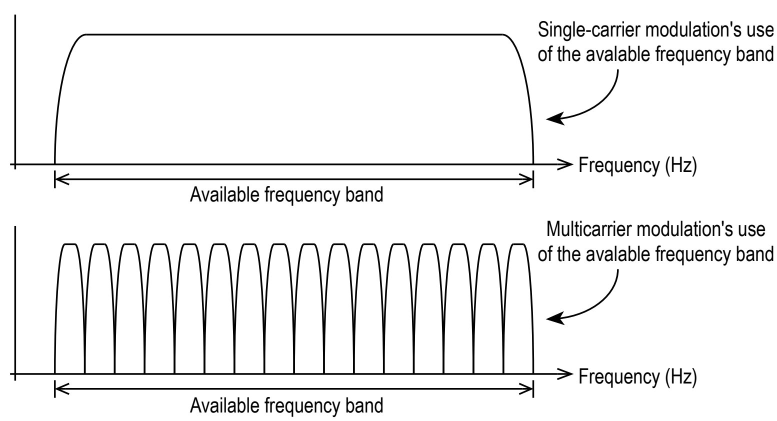
[2] Central offices were historically housed in building in downtowns. Over time, the DSLAMs were also placed in "remote terminals" acting as CO extensions (*e.g.* in a suburb or housing development).

and/or amplified or diminished, typically using a method called quadrature amplitude modulation (QAM)) to indicate the 1's and 0's that comprise digital bits. *See* Fig. 3:

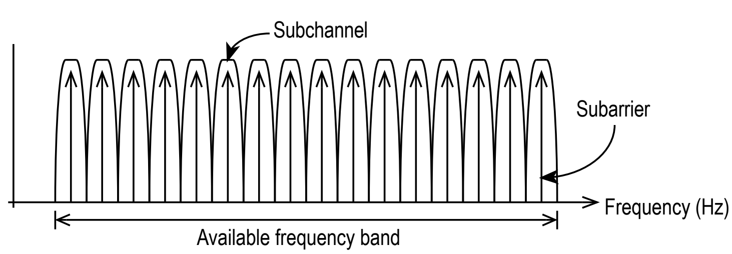


C. <u>DMT Modulation</u>

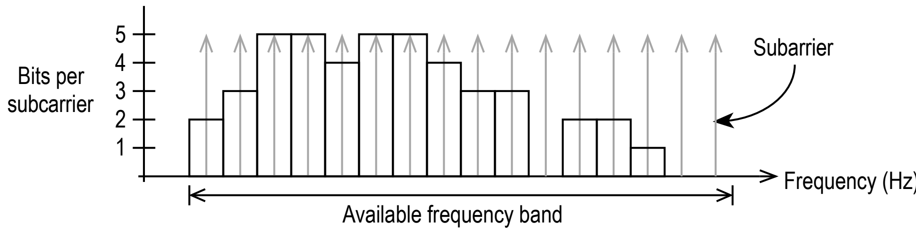
6. All of the DSL types at issue in this case use a technique called *discrete multi-tone* (DMT) modulation to convert data bits into signals sent over the line. DMT modulation is a form of *multicarrier modulation*, to be contrasted with the *single-carrier modulation* described above. In DMT modulation, rather than taking the original data stream and just modulating it on a single carrier, the transmitter breaks up the original digital data stream into groupings and simultaneously modulates the bits onto two or more *subcarriers* (also referred to as *tones* or *carrier signals*).



7. The subcarriers are distributed across the frequency band, and each occupies a *subchannel*:



8. The number of bits allocated to each subcarrier may be different, and some subcarriers might not carry any bits:



9. The number of bits that can be modulated onto each DMT subcarrier is referred to as the *bit loading* or a "bit allocation table" or "BAT."

10. Functionally, each subcarrier operates like an independent modulated single-carrier: it carries a unique signal that represents the particular sequence of bits being transmitted in its subchannel. The DMT transmitter creates the overall signal transmitted over the line by adding together all of the unique signals generated for the subcarriers. Thus, one way to think of a DMT transmitter is as a large number of single-carrier transmitters operating in parallel (hence the name "multicarrier").[3]

11. On the other end of the line, the DMT receiver accepts the received signal, demodulates each subcarrier, divines the communicated bits, and stiches them back together.

III. THE FULL SCOPE OF DSL RULES AND STANDARDS

12. To accomplish high speed transmission, DSL modems must overcome many impairments present in wires originally designed solely for traditional (*i.e.* low frequency) voice

[3] For ADSL1, it is like having 256 separate modems operating on the same line. ADSL2+ achieves higher bit rates by using 512 subcarriers across a 2.2 MHz band, and VDSL2 uses up to 4,095 subcarriers across a much wider band (up to 30 MHz). DMT's effectiveness comes at the cost of very high modem complexity in terms of the number of transistors and the large amount of software and memory.

telephone service. DSL modulations are distorted by echoes, time distortion, crosstalk, signal attenuation variation over frequency, and various types of noise. The techniques to combat these transmission impairments and reconstruct the true/intended signal require numerous complex software algorithms and complex hardware designs (*e.g.* integrated circuit chips).

13. Implementation of a DSL modem is extremely complicated. For example, the DMT transmitter uses a mathematical operation called an inverse discrete Fourier transform (IDFT) to create the signal transmitted over the line, and the receiver uses a complementary discrete Fourier transform (DFT) to recover the data. DMT modulation and many of the other techniques used in DSL modems were once considered as only academic due to the impractically enormous digital signal processing power required, but advances in integrated circuit technology have made the implementation possible.

14. DSL modems include hardware and software to perform a wide range of functions designed to address the challenge of transmitting data over lines laid down decades earlier for an entirely different purpose. Examples include:

- Electronic filters and/or echo cancelers to separate and reduce interference between downstream and upstream DSL signals
- Handshake protocols to allow the modem in the DSLAM and the modem at the subscriber premises to decide on a common mode of operation
- Initialization and training protocols to assess the quality of the line and to select appropriate settings and configurations from among hundreds of options for data rates, power levels, forward error correction parameter values, interleaver parameters, etc.
- Techniques to reduce interference to nearby lines (*e.g.*, upstream power backoff)
- Techniques to reduce interference to/from over-the-air signals
- Frequency-domain equalizers to account for and mitigate the effects of frequency-dependent attenuation the subscriber line causes to signals

- Time-domain equalizers to reduce inter-symbol interference between consecutive symbols
- Insertion of a pilot tone to assist the receiver in maintaining synchronization
- Insertion of an overhead channel in the bit stream to provide control information
- Insertion of a synchronization symbol among the data symbols to allow the modems to recover from micro-interruptions
- Timing recovery algorithm to allow the receiver to detect symbol boundaries in the received signal
- Polynomial scramblers to produce a bit stream that appears to be random (*e.g*. to reduce peak-to-average power)
- Interleaving to reduce the impact of burst errors
- Trellis coding/decoding to spread the data code-space to protect against transmission errors
- Cyclic redundancy check coding/decoding to detect transmission errors
- Reed-Solomon coding/decoding to detect and correct transmission errors
- Framing and multiplexing to combine various data streams including information to control the far-end modem and to provide data paths having different delays
- Interfaces to allow the handling of different types of data (*e.g.*, packets, synchronous data, ATM)
- Cyclic extension and windowing to reduce intersymbol interference and allow use of the IDFT/DFT
- Hardware and software to monitor signal quality and error statistics, and protocols to report this information
- Remote management of subscriber-side modems
- Measurement and reporting analog characteristics of wires and noise
- Multiplexing of data onto DSLAM backplane
- Vectoring to intentionally distort the transmitted signal to mitigate crosstalk to and/or from nearby lines

15. These processes – some patented, some not – are the product of a highly coordinated effort by thousands of engineers.

IV. DSL STANDARDIZATION (E.G. ADSL, ADSL2, VDSL2)

16. There are often multiple ways to accomplish each of the functions and sub-functions summarized above. By way of example only, there are countless algorithms and rules that could be used to interleave to spread data over time to protect against noise bursts. To avoid the risk of different manufacturers adopting different rules that create interoperability problems and modems that cannot talk to each other, the industry has developed rules (*i.e.* "standards") and a process of rule-making so that everyone uses the same rules, steps, processes, etc. In most countries, there is no legal requirement to obey the standards, but there is strong market pressure to comply to the requirements in the industry standards. Chip and equipment vendors implement the requirements in the standards, so they can sell a product throughout the world, thus avoiding the need to develop special products for each country or customer.

17. The effort to standardize DSL technology began in the late 1980's, culminating in the American National Scientific Institute ("ANSI") issuing in 1995 the T1.413 standard. This was the first version of what is known now as "ADSL1."

18. In the late 1990's the standardization effort moved to the Telecommunications Sector of the International Telecommunications Union (ITU-T), an agency of the United Nations that specializes in information and communication technologies. The ITU-T proceeded to release various standards relating to different types of DSL. In 1999, the ITU released the G.992.1 standard, a revision of ADSL1. In 2002, the ITU released the G.992.3 ("ADSL2") standard, which builds on many of the aspects of G.992.1 to enable faster data rates and adds a

number of additional features and capabilities. In 2003, the ITU released the G.992.5 ("ADSL2+") standard, which has an expanded frequency band available for downstream transmission. In 2006, the ITU released the G.993.2 ("VDSL2") standard, which specifies aspects of modems that can transmit at a bidirectional data rate (the sum of the upstream and downstream rates) of up to 200 Mbit/s.

19. Today, thousands of aspects of DSL have been standardized in some of the most complex technical standards in the world. Each standard (*e.g.* ADSL2, ADSL2+, VDSL2) contains a vast number of technical requirements that cover, or at least touch upon, every aspect of DSL modem/DSLAM operation.[4]

V. DSL COMMUNICATION PHASES

20. Across all of the standards at issue in this case, there are three standardized phases of communication in DSL: handshake, initialization, and Showtime. The description below focuses only on the features of the phases relevant to this case.

21. In the first phase of communication, known as "handshake," the DSL modems execute procedures that allow them to exchange capabilities and select a common mode of operation (*e.g.*, ADSL1, ADSL2, ADSL2+, VDSL2, etc.). The handshake procedures are specified in a separate standard, ITU-T Recommendation G.994.1.

22. Handshake is an integral part of the start-up procedure for ADSL2, ADSL2+, and VDSL2, as well as for other standardized types of DSL modems. In particular, handshake

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[4] Further, it is important to note that G.992.3 (ADSL2) and G.993.2 (VDSL2) are not complete specifications for an A/VDSL chip. Many portions of DSL implementation (*e.g.* handshake) are defined by other standards (*e.g.* G.994.1 ("Handshake")) beyond even the massive standards set forth above. All of these additional standards must be implemented for a product to meet most customer requirements.

is the highly choreographed exchange by which two, unfamiliar modems identify and select the best (highest data rate) DSL type that both modems are able to use.

23. After the modems have completed the handshake procedures and agreed on a common mode of operation, they begin to execute the applicable "initialization" protocol for that mode.[5] A primary objective of initialization is to determine the DSL modem settings that will be used during the third phase of communication (Showtime). The modem in the DSLAM may have different capabilities and limitations than the subscriber's DSL modem. Furthermore, the quality of the line between the two DSL modems has a significant impact on the settings, such as the number of bits that can be carried by each subcarrier.

24. One purpose of initialization is therefore to configure the settings and components of the modems, optimizing them for the channel conditions and constraints in the line. The two modems transmit sequences of specially-designed signals that allow them to determine the settings and configurations they will use for the connection. The modems can also "train" other components based on the conditions of the line.

25. Among the things determined during initialization is the bit loading, which is dependent on the *signal-to-noise ratio* (SNR) of each subcarrier. The receiver estimates the SNR of each subcarrier on which it can potentially receive data. It then determines the number of bits each subcarrier will support during Showtime. In determining the bit loading, the receiver imposes a *noise margin* that results in each subcarrier carrying fewer than the maximum number of bits it could carry. Essentially, the noise margin provides a cushion in case

[5] DSL is intended to be an "always on" service. As a result, DSL modems stay in Showtime for long periods of time. Typically, after service installation, DSL modems start-up on the order of once a month or less.

the SNR for a given subcarrier degrades after the connection has been established. Before the end of initialization, the receiver communicates the bit loading (*i.e*. the number of bits per subchannel) to the transmitter.

26. The initialization procedure is followed by "Showtime," during which the DSL modems transfer user data.[6] During Showtime, the transmitter uses the bit loading to modulate bits onto the subcarriers, and the receiver uses the bit loading to recover the bits from the received subcarriers. The transmitter and receiver must use the same bit loading at all times.

27. As the connection progresses, the channel characteristics, noise, services being provided, or other aspects of the connection may change, causing the original negotiated settings to become suboptimal. Modems can modify their settings to adapt to changes to the channel, noise, or service requirements by using procedures referred to as *on-line reconfiguration* (OLR).

28. The DSL standards define a variety of types of OLR. One type is *bit swapping*. Bit swapping allows the receiver to instruct the transmitter on the other side of the line to make a change to the (i) bit loading and (ii) power allocation to compensate for changes in the subcarrier SNRs over time. For example, if the receiver detects that the SNR of a subcarrier has decreased substantially, the receiver can instruct the transmitter to load fewer bits onto that subcarrier and to load more bits onto another subcarrier that has sufficient SNR to accommodate additional bits. Bit swapping does not change the overall data rate of the connection.

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[6] Showtime is so named because in the early days of ADSL, video-on-demand was envisioned as the key application, and the show would start after initialization was complete. Although Internet access ended up being the earliest driver of DSL deployment and adoption, the name "Showtime" has endured.

29. Bit-swapping predates the patents-in-suit. The phenomenon of channels changing over time has been known since at least 1993, *see, e.g.*, T1E1.4/93-184, and some form of responsive bit-swapping – indeed, called "bit-swapping" by name – has been baked into the DSL standards since 1995 (ADSL1) (*i.e.* before the priority date of the patents-in-suit). *See* T1.413 (1995) at § 13.2.

VI. THE PATENTS-IN-SUIT

A. The '735, '532, and '275 Patents

30. The '735, '532, and '275 patents purport to be directed to adaptive allocation of bandwidth in DSL systems, essentially a tweak on preexisting bit-swapping techniques.

31. As noted above, it has been known since at least 1993 that as a DSL connection ages, the number of bits that can be carried by each subcarrier may change due to changes in the channel characteristics or noise. *See, e.g.*, T1E1.4/93-184.

32. The bit swap protocols in existence as of the priority date of the '735, '532, and '275 patents (*e.g.*, the bit-swapping specified in ADSL1) allowed the receiver to send a request to the transmitter to modify a small number of subcarriers. Typically, the request would be to remove one bit from a particular subcarrier and add one bit to another subcarrier (hence the name "bit swap"). As a result, the total number of bits in the bit allocation table would remain the same, but they would be distributed slightly differently.

33. The '735, '532, and '275 patents describe a different way of updating the allocation of bits to subcarriers. In the patents, the modems on each end of the line maintain multiple bit allocation tables, two for the downstream direction, and two for the upstream direction. When a change is needed in one of the directions, the transmitter and receiver swap out the *entire* current bit allocation table in favor of the other bit allocation table. *See, e.g.*, '275 patent, 1:48-54, 2:58-3:2, 4:61-5:16.

34. The patents describe (1) the transmitter and receiver operating with a current bit allocation table while the receiver builds the new bit allocation table ('275 patent, 5:17-18, 5:35-36), (2) the receiver communicating the new bit allocation table to the transmitter on the other end of the line, (*id.* at 5:25-27), (3) either the transmitter or receiver sending a "flag" to the other modem, (*id.* at 5:38-40, 11:42-46), and (4) the transmitter and receiver simultaneously switching to the new bit allocation table (*id.* at 5:40-43). The flag is sent over a reserved subcarrier that can also be used to convey the new bit allocation table. *Id.* at 11:42-51.

35. In short, the patents disclose the two modems swapping *entire* BAT tables, *i.e.* complete lists of how many bits will be assigned to all subcarriers.[7]

B. The '068 and '171 Patents

36. The '068 and '171 patents are directed to the concept of variable state length initialization for DSL systems, whereby both the transmitter and the receiver can adjust the duration of initialization – ultimately to yield a 2-4 second time savings a few times per year, typically in the dead of night.

37. DSL modems include hardware and software that is "trained" during initialization to determine initial settings. This hardware and software includes equalizers and/or an echo canceler. To allow these components to be trained, the transmitter sends specially-designed signals during initialization.

38. The equalizers are trained using signals transmitted by the far-end modem.

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[7] Until the deposition of IV's technology expert, both parties appeared to have the same understanding of this aspect of the patents. However, at his deposition, IV's expert departed from his report and argued that the patents (despite using terms like "*the* table") actually cover swapping "*part* of a table." While we do not credit IV's revised reading of the patents (Frontier does not infringe under a proper reading), IV's change of heart ultimately makes no difference to the ultimate question before the Court at the upcoming hearing, though it certainly undermines IV's expert's credibility.

The echo canceler is trained using signals transmitted by its own transmitter.

39. Different modems may require different amounts of time for training equalizers versus echo cancellers.

40. The patents address the "problem" of allowing just one side/modem to control the length of certain states of initialization. *See e.g.*, '068 patent, 1:33-2:3; *see also* ITU-T SG15/Q4 contribution IC-094 (April 9, 2001). The purported contribution of the patents is to allow a DSL transmitter and receiver to both negotiate the duration of certain initialization states. Specifically, the patents describe a transmitter, during initialization, being able to inform the receiver on the other end of the line of the minimum duration the transmitter needs a particular initialization signal to be, and then transmitting at least that duration of the signal.

41. This purported invention allows the modems to negotiate a training time sufficient for both ends that is less than the maximum allowed in the standard. The time savings is approximately 2-4 seconds per initialization, a function that occurs only a few ties per year, typically at night, typically unknown to the customer.

42. Significantly, the '068 and '171 patents are *not* directed to, and do not purport to claim, eliminating such initializations altogether (which occur for reasons having nothing to do with the patents-in-suit). Rather, the '068 and '171 patents propose a negotiation process that could slightly reduce these (infrequent) initializations from about 60 seconds to 56-58 seconds, a 2-4 second savings every few months – in the dead of night, out of most customers' view.

VII. CONCLUSION

43. The patents-in-suit—set in their technical context—are directed to a miniscule portion of DSL's features and functions (Section III *supra*) and, unsurprisingly, a tiny portion of the related standards (Section IV *supra*). And as the Venn diagram (Fig. 1) above makes

clear—and as will be explored in Frontier's trial brief—the patents-in-suit represent a tiny portion of the patents and technologies asserted and ultimately licensed in the allegedly comparable suits.

Dated: April 22, 2022

Respectfully submitted,

FRONTIER COMMUNICATIONS
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CERTIFICATE OF SERVICE

I hereby certify that on April 22, 2022, I caused a true and accurate copy of the foregoing document to be served on the counsel for Intellectual Ventures II LLC by filing the foregoing via the Court's ECF system.

/s/ Timothy R. Shannon
Timothy R. Shannon